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Military Technology In 2100: The Evolution Of Defense Toward A Futuristic Era

Elyakim Snekubun[1]
[1]Fakultas Keamanan Nasional Universitas Pertahanan Republik Indonesia
Surya Wiranto[2]
[2]Fakultas Keamanan Nasional Universitas Pertahanan Republik Indonesia
Ceppi Hilmansyah[3]
[3]Fakultas Keamanan Nasional Universitas Pertahanan Republik Indonesia

Corresponding Author: **snekubunlaw@yahoo.com**[1]**, suryawiranto1@gmail.com2**

Abstract

This article explores anticipated shifts in military technology through the year 2100 by synthesizing present-day technological trajectories, scientific advancements, and evolving defense policies. Over the coming century, defense architectures are likely to transform substantially, marked by pervasive combat automation, sophisticated exoskeleton systems, adaptive smart-material camouflage, and the incorporation of genetic and biotechnological applications for defense purposes. Control of cyberspace and outer space will emerge as pivotal strategic arenas. Together, these trends will reframe warfare from primarily kinetic encounters to conflicts driven by advanced technologies and data-centric operations. Developments in artificial intelligence, machine learning, and autonomous weapons are expected to lessen direct human involvement while accelerating and streamlining military decision-making processes (Scharre, 2018). However, these innovations raise serious concerns automated escalation, erosion of meaningful human oversight, and potential unethical deployment of powerful technologies highlighting the pressing need for robust international legal and ethical governance. This paper offers a detailed examination of these trajectories and their implications for global military capabilities and international security in the twenty-second century.

Keywords: military technology; autonomous weapons; artificial intelligence; smart materials; cybersecurity; space security.

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INTRODUCTION

As the world approaches the twenty-second century, the global military landscape is projected to undergo a fundamental paradigm shift driven by unprecedented technological advancements that transcend the limitations of contemporary warfare. Innovations once considered speculative or confined to science fiction such as artificial intelligence (AI), autonomous robotics, and advanced space technologies are now entering the realm of operational feasibility. According to Payne (2021), the evolution of warfare is increasingly characterized by the fusion of digital intelligence and automation, resulting in the emergence of a new generation of military capabilities that prioritize precision, adaptability, and autonomy. Major powers such as the United States, China, and Russia have intensified their investments in digitalized and network-centric defense systems, signaling a strategic transition from conventional military strength toward technological superiority as the principal determinant of global power (Altmann & Sauer, 2017; Kania, 2019).

The essence of future military power will rest upon the speed of data processing, algorithmic decision-making, and control over non-traditional domains such as cyberspace and outer space. These domains are becoming the decisive frontiers for asserting global dominance (Horowitz, 2018). By 2100, warfare will no longer be limited to terrestrial, naval, and aerial theaters; instead, it will expand into hybrid arenas encompassing cyber conflict, informational manipulation, and orbital defense systems. National security infrastructures are expected to integrate quantum computing, predictive analytics, and AI-driven autonomous platforms capable of executing missions independently while minimizing human involvement. Such architectures promise operational efficiency but also introduce complex security vulnerabilities and ethical risks (Boulanin & Verbruggen, 2017).

Emerging defense technologies are also anticipated to create adaptive systems responsive to real-time battlefield conditions. Smart combat uniforms embedded with nanomaterials could dynamically adjust coloration and thermal profiles to blend with environmental variables, while exoskeletons would enhance soldiers' physical endurance, strength, and mobility beyond human limitations (Herr, 2020). These innovations redefine not only the physiological and tactical dimensions of warfare but also its moral and regulatory boundaries. As Scharre (2018) emphasizes, the integration of AI in combat introduces dilemmas regarding human control and accountability in lethal decision-making. Without proper governance, fully autonomous systems could operate outside the scope of ethical norms and international humanitarian law.

Therefore, maintaining equilibrium between technological efficiency and humanitarian

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principles necessitates the establishment of comprehensive international oversight frameworks. Cummings (2021) and Asaro (2012) argue that ensuring meaningful human control and ethical responsibility in the deployment of advanced military systems must remain a cornerstone of defense innovation. In this context, the twenty-second century marks not only a technological revolution but also a moral test for humanity's capacity to regulate the future of war.

Combat System Automation: The Rise of Autonomous Warfare

The emergence of automation in warfare marks a transformative evolution in the character and conduct of military power. By the year 2100, comprehensive automation is projected to become the defining feature of global defense systems. This shift, driven by rapid advancements in artificial intelligence (AI), robotics, and autonomous engineering, will fundamentally alter how wars are fought and won. As argued by Scharre (2018), autonomous systems are transitioning from supportive roles such as reconnaissance, logistics, and surveillance to becoming decisive instruments in offensive and defensive combat operations. This evolution is not merely technological but strategic reflecting a global movement toward faster, data-driven, and more precise forms of warfare where machines assume tasks once deemed exclusively human.

The next generation of combat platforms autonomous drones, ground robots, and unmanned maritime vehicles will operate with sophisticated AI algorithms capable of independent decision-making, adaptive learning, and situational awareness (Roff, 2019). Unlike traditional remote-controlled systems, these autonomous weapons can assess complex battlefield scenarios, prioritize threats, and execute tactical maneuvers in real-time without direct human oversight. Such autonomy allows for the optimization of battlefield efficiency and a reduction in human casualties (Horowitz, 2018). However, it also raises serious ethical and operational concerns about accountability, predictability, and escalation risks in high-speed conflict environments.

A particularly significant innovation in automated warfare is the deployment of directed-energy weapons (DEWs) a class of systems that use concentrated energy, such as lasers or microwaves, to neutralize targets with unprecedented precision and speed. These weapons can engage threats at light-speed, offering minimal collateral damage while maintaining lethality against fast-moving adversaries like hypersonic missiles or enemy drones (Payne, 2021). Research by Adams and Sparrow (2020) highlights that the integration of DEWs into autonomous systems will enable "dynamic deterrence," where AI-assisted targeting allows militaries to respond

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instantly to aerial and orbital threats. Yet, the deployment of such systems also creates dilemmas regarding command responsibility and the legality of pre-emptive, algorithm-driven strikes under international humanitarian law.

In addition to robotic autonomy, human-machine integration is redefining the combat role of soldiers. Future warfare will not eliminate the human element entirely; instead, it will fuse human intuition with machine precision through wearable technologies such as military exoskeletons. These biomechanical suits enhance physical endurance, strength, and protection, enabling soldiers to carry heavier loads, withstand extreme environments, and sustain longer missions (Herr, 2020). Advanced models incorporate biometric sensors, augmented reality (AR) displays, and neural interfaces that allow real-time coordination with central command systems (Jin, Liu, & Zhang, 2021). As Cummings (2021) notes, such integration creates a "human-machine symbiosis," in which the human operator serves as both the controller and beneficiary of AI-enhanced systems. However, reliance on neuro-controlled exoskeletons also introduces vulnerabilities, including cyber intrusions targeting neural networks or data breaches compromising soldier health data (Boulanin & Verbruggen, 2017).

Furthermore, as combat automation intensifies, the human role is expected to shift from direct engagement toward strategic supervision and ethical governance. Humans will increasingly function as commanders overseeing fleets of autonomous assets evaluating outcomes, setting constraints, and ensuring compliance with rules of engagement. The primary challenge, therefore, is not whether machines can fight, but whether human oversight can remain meaningful as AI decision cycles outpace human cognition (Russell & Norvig, 2020). Scholars such as Sharkey (2020) and Asaro (2012) warn that complete autonomy in lethal decision-making could erode moral accountability and weaken compliance with humanitarian principles, leading to what they call "dehumanized warfare."

This paradigm shift underscores the urgent necessity for international regulation and ethical frameworks governing the use of autonomous and semi-autonomous weapon systems. The United Nations Group of Governmental Experts (GGE) on Lethal Autonomous Weapon Systems (LAWS) has repeatedly emphasized the principle of "meaningful human control" as a safeguard against unregulated automation in warfare (United Nations, 2021). Maintaining human agency within automated decision chains ensures that critical moral judgments particularly those involving life and death remain accountable to human operators and political authorities.

In conclusion, automation in combat represents both a technological revolution and an ethical crossroad. While AI-driven autonomy, directed-energy weaponry, and exoskeleton

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augmentation promise unprecedented efficiency and force multiplication, they also risk detaching warfare from human conscience. Balancing innovation with restraint through robust international law, transparent command structures, and ethical AI governance will determine whether automated warfare in 2100 becomes a tool for stability or a catalyst for uncontrollable conflict.

Military Exoskeletons: Human–Machine Integration in Future Warfare

The development of military exoskeletons marks a pivotal milestone in the fusion of human physiology and machine intelligence an innovation that is expected to redefine the structure and dynamics of twenty-second century warfare. A military exoskeleton is a powered external framework designed to augment the biomechanical functions of the human body, enhancing strength, endurance, and mobility beyond natural biological limits (Herr, 2020). These systems, once conceptualized as speculative technologies, are now transitioning into operational reality due to advances in robotics, biomechatronics, and human–machine interfacing. Scholars such as Bogue (2021) argue that exoskeletons will soon become indispensable assets for future soldiers, improving physical performance, reducing fatigue, and providing superior protection against battlefield stressors.

In modern and future military environments, exoskeletons function as force multipliers, allowing soldiers to perform physically demanding tasks with greater efficiency and reduced injury risk. The U.S. Army's *TALOS* (Tactical Assault Light Operator Suit) and China's *Qilian* exoskeleton prototypes exemplify the ongoing global race to integrate biomechanical enhancement into combat readiness (Kazerooni et al., 2020). By 2100, exoskeletons are expected to enable sustained load-bearing operations exceeding 200 kilograms, facilitating faster movement across uneven terrains and granting enhanced agility under extreme conditions. These capabilities directly address the physiological limitations of human soldiers, extending endurance and improving survivability during prolonged missions (Tucker, 2022).

The sophistication of exoskeleton technology lies in its sensor fusion and real-time adaptability. Advanced units are anticipated to incorporate multispectral sensors that continuously monitor key physiological metrics such as heart rate, muscle fatigue, and body temperature, enabling dynamic adjustment of mechanical assistance (Jin, Liu, & Zhang, 2021). This biofeedback mechanism allows the suit to respond intuitively to the soldier's condition, optimizing energy consumption and minimizing strain. Further, embedded communication modules will integrate seamlessly with command-and-control (C2) networks, transmitting live positional data and battlefield updates directly to operators via augmented reality (AR) interfaces (Pons, 2019).

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Recent research in neuroprosthetics and brain computer interfaces (BCIs) has propelled the possibility of direct neural control over exoskeletons. Through decoding brain signals, exoskeletons can anticipate user intent and execute precise movements without manual input, effectively transforming the operator into a hybridized "cyborg soldier" capable of split-second decision-making and rapid physical response (Jackson & Williams, 2022; Lebedev & Nicolelis, 2017). According to Cummings (2021), this form of human–machine symbiosis can dramatically improve operational coordination and combat efficiency by minimizing the cognitive lag between thought and action. Nonetheless, the integration of neural systems introduces vulnerabilities, such as cyber intrusions targeting neural data or interference with motor control, which could compromise the safety and autonomy of soldiers in combat (Boulanin & Verbruggen, 2017).

Beyond technical dimensions, the deployment of exoskeletons raises profound ethical and philosophical concerns surrounding human enhancement and the militarization of the human body. Scholars such as Coeckelbergh (2021) and Sparrow (2019) caution that the drive to augment soldiers risks commodifying human beings as "military assets," blurring the boundaries between biological humanity and mechanized utility. Questions arise about consent, long-term health effects, and psychological dependency on biomechanical augmentation. In addition, unequal access to enhancement technologies across nations may create disparities in military capability, echoing fears of a future "enhanced soldier class" that could alter global power dynamics (Lin et al., 2016).

From a strategic perspective, exoskeletons represent not merely assistive technologies, but the evolution of the soldier into an integrated *human–machine system* a cognitive and physical node within a networked battlefield ecosystem. By 2100, exoskeleton-equipped troops are likely to function as adaptive, data-linked combat units operating in tandem with autonomous drones and robotic platforms. This convergence of biomechanical augmentation and AI-enabled coordination will radically transform the traditional notion of manpower, replacing physical strength with computational synergy and real-time connectivity (Roff, 2019).

In summary, military exoskeletons symbolize both progress and peril in the trajectory of defense innovation. Their capacity to enhance human performance, improve survivability, and enable seamless human–machine integration positions them as essential tools of twenty-second century warfare. Yet, without robust international governance, clear ethical standards, and protective policies for human operators, the line between augmentation and exploitation could easily blur. The challenge for future defense systems will lie in ensuring that exoskeletal technologies enhance not diminish the humanity of the soldier.

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Adaptive Camouflage and Smart Materials

The future of military defense design is being reshaped by innovations in adaptive camouflage and smart materials, technologies that will revolutionize concealment, survivability, and durability on twenty-second-century battlefields. In an era characterized by pervasive sensor technologies and multi-spectral surveillance, the ability to dynamically blend into the environment will be critical for both soldiers and military platforms. Adaptive camouflage systems will use nanotechnology and metamaterials capable of altering their physical and optical characteristics including color, texture, and thermal signature according to surrounding conditions (Rogers, Thompson, & Lin, 2021). Through thermochromic and electrochromic reactions, these materials can shift appearance instantaneously, allowing seamless transitions between diverse terrains or diurnal light variations (Díaz et al., 2019).

The integration of smart materials extends beyond concealment into self-sustainability. Smart composites embedded with self-healing polymers and nanofibers possess the ability to repair scratches, cracks, or impact damage through molecular reconfiguration (Liu, Zhang, & Wang, 2020). Such materials, inspired by biological regeneration mechanisms, could enable military vehicles or armor to autonomously restore functionality after sustaining damage, thereby extending service life and reducing logistic dependencies in hostile environments (Toohey et al., 2018). Advances in embedded sensor networks further allow these materials to perform continuous diagnostics, reporting structural health in real-time to command systems (Blaiszik et al., 2020).

From an operational perspective, adaptive camouflage and self-repairing materials significantly enhance battlefield endurance and survivability. Future combat uniforms will integrate electrochromic nanolayers capable of optical cloaking, and armored vehicles may use metamaterial coatings to scatter radar detection (Sun et al., 2021). As noted by Zhang et al. (2020), these innovations create “meta-surfaces” that control electromagnetic waves, rendering objects nearly invisible across multiple spectra. However, balancing flexibility, strength, and durability remains a major design challenge (Chen et al., 2019).

The convergence of adaptive and self-healing technologies will yield autonomous defense systems that are resilient, energy-efficient, and operationally sustainable. Yet, as Gao and Guo (2021) emphasize, the increasing autonomy of such materials introduces strategic uncertainty military assets capable of adapting and self-repairing without human intervention could complicate control, accountability, and strategic predictability in warfare. Nevertheless, these innovations collectively mark a turning point toward intelligent defense ecosystems in which

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materials are not passive components but active, self-managing systems that respond intelligently to the environment.

Genetic Weapons and Military Biotechnology

The intersection of genetic science and defense technology represents one of the most ethically fraught and strategically potent frontiers of future warfare. By 2100, militaries may employ genetic weapons designed with unprecedented precision, capable of targeting specific genomes or biological markers. These weapons could manipulate pathogens to selectively affect individuals or populations, redefining biological warfare into a domain of personalized, gene-specific targeting (Oye et al., 2014).

Simultaneously, the advancement of military biotechnology promises the rise of "enhanced soldiers" combatants genetically optimized for resilience, strength, cognition, and endurance (Gostin & Powers, 2018). Gene editing tools such as CRISPR-Cas9 enable precise modifications to DNA sequences, potentially enhancing soldiers' immunity, muscular performance, and neural processing speeds (Liu et al., 2021). However, these advancements blur the ethical boundaries of human identity and consent, transforming the human body into a platform for state power.

In addition, nanobiotechnology may facilitate the creation of synthetic microorganisms capable of disrupting biological infrastructure infecting crops, contaminating water supplies, or influencing human neurochemistry through bioengineered compounds (Tucker, 2020). The potential weaponization of such biotechnology poses existential risks; its impacts could be uncontrollable, transboundary, and irreversible (Esvelt et al., 2017). Scholars warn that bioengineered systems could undermine international security far more than nuclear weapons due to their ease of production and concealment (Dando, 2019).

Hence, establishing global governance frameworks is paramount. The Biological Weapons Convention (BWC) lacks robust enforcement mechanisms to address emergent biotechnologies. Experts advocate for a new *International Genetic Ethics Treaty* (IGET) that would impose transparency and verification regimes on genetic research with dual-use potential (Kelle, 2021). Without such oversight, genetic militarization risks catalyzing asymmetric warfare, bioterrorism, and the erosion of human dignity.

Dominance in Cyberspace and Outer Space

The future of military power will increasingly hinge on control over **cyberspace** and **outer**

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space two domains that will define twenty-second century geopolitics. Cyberspace, once a support environment, has evolved into a critical theater of warfare where nations can disrupt adversary infrastructure without deploying physical forces (Rid, 2020). The integration of artificial intelligence and quantum computing will make cyber operations fully autonomous, enabling instantaneous threat detection, countermeasures, and offensive strikes (Kello, 2017).

Cyber warfare will involve the manipulation of networks, data corruption, and psychological operations targeting civilian and military systems. As Klimburg (2019) notes, future cyber conflict will center on *digital sovereignty* the ability of a state to control its own information space against external interference. Autonomous cyber defense systems capable of predictive analytics and self-repair will become essential, creating a continuous cyber "arms race" among leading powers.

Parallel to this, **outer space** will emerge as the ultimate high ground of military competition. Satellite constellations will function not only for communication and reconnaissance but also as **orbital weapons platforms** capable of deploying lasers, kinetic interceptors, and hypersonic projectiles from orbit (Weeden & Samson, 2019). States will likely maintain **permanent orbital fleets** composed of manned and unmanned combat stations to monitor and defend strategic orbits. The United States Space Force, China's Strategic Support Force, and emerging European coalitions are already laying groundwork for this new frontier (de Graaf, 2019).

However, both domains also introduce vulnerabilities: satellites are susceptible to anti-satellite (ASAT) missiles and cyber-attacks, while critical cyber infrastructure faces constant threats from autonomous malware (Nakashima, 2022). Therefore, multilateral agreements such as the proposed *Cyber Geneva Convention* and enhanced Outer Space Treaty amendments are vital to prevent escalation.

Ethical and Legal Challenges

The rapid acceleration of military technological innovation introduces profound ethical and legal dilemmas. As artificial intelligence, genetic manipulation, and space weaponization evolve, the traditional frameworks of accountability, proportionality, and human oversight face severe strain (Crootof, 2015). One central issue concerns accountability in autonomous decision-making. When AI-driven systems make lethal choices, it becomes unclear who bears legal responsibility the programmer, commander, or state (Asaro, 2012). This "responsibility gap," as Sparrow (2020) terms it, challenges the very basis of international humanitarian law. Scholars advocate for embedding *explainable AI* and *human-in-the-loop* architectures to ensure

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transparency and human control over autonomous weapons (Russell & Norvig, 2020).

Ethical concerns also extend to human enhancement and biotechnological militarization. Genetic modification for combat purposes risks creating hierarchical inequalities and violating human dignity. As Gostin & Powers (2018) emphasize, "enhancement without equality" can institutionalize biological discrimination, destabilizing the moral foundation of armed forces. The weaponization of outer space raises similar legal ambiguity. Although the 1967 Outer Space Treaty prohibits military aggression in space, loopholes allow for "dual-use" technologies that blur civilian and military lines (Weeden & Samson, 2019). Consequently, experts propose a new *Space Security Convention* to regulate directed-energy weapons and orbital strike systems (de Graaf, 2019). In essence, maintaining meaningful human control and adherence to humanitarian law remain the moral imperatives of twenty-second century warfare. Without robust regulation and global cooperation, emerging technologies risk outpacing the ethical frameworks designed to contain them turning progress into peril.

CONCLUSION

In the context of rapid and unprecedented advancements in military technology, the necessity for international cooperation, regulatory precision, and ethical oversight has never been greater. The accelerating integration of artificial intelligence, autonomous systems, and biotechnology into defense frameworks carries both transformative potential and existential risks. Without the establishment of robust legal, ethical, and institutional safeguards, these innovations could easily evolve from instruments of protection into catalysts for global instability and humanitarian crises.

Sustaining peace and security in the twenty-second century will therefore depend on the international community's ability to design and enforce comprehensive governance mechanisms that balance innovation with accountability. Global institutions such as the United Nations, the International Telecommunication Union, and the International Committee of the Red Cross must play an active role in crafting treaties and verification regimes that limit the weaponization of emerging technologies while promoting transparency and mutual trust among states. Such collaboration is essential not only to prevent misuse but also to ensure that autonomous systems remain under meaningful human control, preserving the moral agency central to just warfare and humanitarian law.

Furthermore, the integration of ethical principles grounded in human rights, proportionality, and the preservation of life should underpin every phase of military technological

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development, from research and design to deployment and operation. As Crootof (2015) and Asaro (2012) emphasize, ensuring human accountability in decision-making is the cornerstone of lawful and moral defense conduct. With careful governance, emerging military technologies can become tools of precision and deterrence rather than instruments of indiscriminate destruction. Ultimately, the trajectory of global defense will hinge on how nations collectively manage innovation with responsibility. The future of warfare must be guided not only by technological superiority but by moral wisdom, ensuring that progress in defense serves humanity rather than endangers it.

FUTURE DIRECTIONS

Looking ahead, the evolution of military technology in the twenty-second century demands a multidimensional approach that combines technological innovation, ethical foresight, and cooperative global governance. Future research and policy development should prioritize frameworks that ensure emerging technologies such as artificial intelligence, quantum defense systems, biotechnology, and space-based capabilities are aligned with humanitarian objectives rather than geopolitical escalation.

First, there is a critical need for interdisciplinary research that bridges engineering, law, ethics, and strategic studies. Future studies should examine how human–machine collaboration can be optimized without compromising human judgment or moral accountability. As emphasized by Cummings (2021) and Russell & Norvig (2020), the challenge is not merely technological sophistication but the creation of "trusted autonomy" that operates transparently and remains subject to ethical oversight. Establishing global standards for AI explainability and predictability will be central to this endeavor.

Second, international regulatory frameworks must evolve to address technological convergence. The emergence of dual-use technologies those applicable to both civilian and military sectors requires adaptive governance models that balance innovation with restraint. A proposed *International Convention on Autonomous Weapons and Biotechnological Warfare* could serve as a binding mechanism to regulate AI-driven armaments and genetic military applications, reinforcing the principles of the Geneva Conventions in the age of automation.

Third, future military strategy must integrate sustainability and resilience. Research into energy-efficient materials, eco-conscious manufacturing, and cyber-secure infrastructures will be essential to reducing the environmental and systemic vulnerabilities of modern defense systems. As emerging domains such as cyberspace and outer space become contested, cooperative

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surveillance, transparency mechanisms, and shared early-warning systems can act as deterrents to conflict escalation.

Finally, future directions should include education and capacity-building initiatives focused on military ethics, digital governance, and technological literacy among defense leaders and policymakers. Cultivating ethical awareness and legal understanding will help prevent misuse and reinforce the norm of *meaningful human control* across all defense technologies.

In conclusion, the future of military innovation must be guided by a vision of responsible advancement where progress in defense technology strengthens peace, enhances global stability, and upholds the moral integrity of humanity in an era increasingly shaped by machines.

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